DOE/ER/41249-1

1^+-n^+ ECR ION SOURCE DEVELOPMENT TEST STAND

Closeout report

April 2006

Donald P. May

PREPARED FOR THE UNITED STATES DEPARTMENT OF ENERGY
OFFICE OF SCIENCE

Work Performed Under Contract No. FG02-04ER41249

Abstract. A test stand for the investigation of 1^+-n^+ charge boosting using an ECR ion sources is currently being assembled at the Texas A&M Cyclotron Institute. The ultimate goal is to relate the charge-boosting of ions of stable species to possible charge-boosting of ions of radioactive species extracted from the diverse, low-charge-state ion sources developed for radioactive ion beams. Because the two ECR ion sources at the Institute serve as injectors for the K500 cyclotron and because both sources have had problems, the investigation has not yet begun. However, both sources have been repaired, the optics for the analysis beam-line for one of the sources has recently been improved, and all the major test-stand components have been acquired so testing can begin soon on this ion source. Some modification to the optics for the analysis beam-line for the other source still needs to be accomplished before it becomes available for testing.

Introduction

The purpose of this test stand is to study the method of using an ECR ion source to boost the charge states of singly-charged ions extracted from another ion source. At the Texas A&M Cyclotron Institute there are two ECR ion sources: ECR1, an ECRIS using 6.4 GHz microwave excitation and ECR2, an ECRIS now using 14.5 GHz microwave excitation but designed to use a combination of 14.5 and 11 GHz microwave excitation. The source of singly-charged ions for the test stand is an alkali ion gun with interchangeable buttons that provide a choice of lithium, sodium, potassium, rubidium or cesium. The ion gun is mounted to a transport beam-line with associated vacuum system, collimation, focusing and magnetic selection. The test stand will be mounted on each source in turn. The study focuses on finding out the important parameters for efficiency of conversion to high-charge states and hold-up times in the ECRIS for light to heavy ions. These parameters include both the characteristics of the input beam (brightness, emittance, atomic number, etc.) and the operational characteristics of the ECR ion source (magnetic field, microwave injection, geometry, etc).

Preparations

Since the ECR ion sources are intended for the injection of beams into the K500 cyclotron, and the cyclotron program continues 24 hours a day on a year round basis, it is difficult to fit charge-boosting tests into the schedule and impossible if there is a problem with either source, and there have been problems with both.

First, a defect in the permanent magnet material of the ECR1 hexapole was causing a reduced magnetic field over a small area at the wall near the center of the source. This defect had led plasma leakage which began to melt a small area of aluminum on the plasma-chamber wall. The microwave power level was limited before the wall was broken through. As a consequence, the source performance was degraded in both total output and stability. Eventually, the plasma chamber was pulled from the source, and the defective hexapole bar was replaced by a newly assembled one. The stability and performance of ECR1 improved dramatically.

Until recently, the ECR2 source had been plagued with a water leak into the plasma chamber, so a new plasma chamber with a water-cooling scheme, isolated from the vacuum, was fabricated. This scheme also allowed for a large increase in cooling capacity. Cooling of the wall of the plasma chamber in the region of the poles of the hexapole was critical to protecting the permanent magnet material and the wall from the hot plasma.

Soon after the new plasma chamber was installed and the source turned on again, the analysis beam-line was modified by replacing the first focusing solenoid with a Glaser lens. The advantage of the Glaser lens over the solenoid was a much shorter focusing length. Comparing the measured intensities of the different charge states of an oxygen beam after analysis with the current drawn from the high-voltage power supply of ECR2 extraction, 37% of the beam was transmitted to the analysis faraday cup with 10 kV , and 45% of the beam was transmitted with 12 kV.

ECR2 is now online and working properly. Earlier a SIMION beam-tracing study had been carried out at Argonne National Laboratory on the behavior of the singly charged beam through the magnetic field mirror along the axis of our source and through deceleration elements into the source. This has guided the design of the injection elements that lead the singly charged beam along axis into the source, with the inclusion of a biased ring at the injection end of the source. This ring will act as the final deceleration electrode as well as take the place of the biased disk that is routinely used to amplify the performance of the ion source.

Plans

First the effect of the injection geometry on the operation of ECR2 will be tested. Since in this geometry a grounded tube is inserted through the injection steel plug into the vacuum chamber there is the possibility of significant extraction of ions from the plasma into this tube. Also in this geometry the on-axis biased disk is replaced by an on-axis biased ring with a possible consequence to the behavior of the source. With just these elements in place and with a Faraday cup on the end of the grounded tube opposite the source changes in operation and backward extraction of plasma into the injection line can be noted and measured. While these tests are ongoing the alkali ion gun can be mounted on the first leg of the test stand and the beam measured. Finally, the entire injection line can be mounted on ECR2. When ECR1 is moved to its new, more forward position, the injection line can be relocated to that ion source.